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How the Benefits, Results and Barriers of Collaboration Affect University Engagement with Industry

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Abstract

Literature has been paying greater attention to the main drivers of academic researchers' engagement with industrial partners. However, there is a lack of understanding of how academic researchers' perceived outcomes and constraints affect their collaboration with firms. The novelty of this article is its analysis of how researchers' perception of the benefits, results, and barriers associated with collaboration affects academic research groups' engagement with industry. We use a comprehensive database on university–industry collaboration from a survey with academic researcher groups in Brazil, and we use a time lag to analyse the number of collaboration of the research groups. We find that perceived intellectual benefits and commercial results are important drivers for researchers' engagement with industry, and economic benefits and transactional barriers are obstacles to increase collaborative projects with firms.

Key words: university–industry collaboration; knowledge and innovation; university; academic collaboration.

1. Introduction

Academic research plays a relevant role in innovation. It is widely accepted in the literature that universities are an important source of new scientific and technological knowledge and that university–industry linkages are vital channels for accessing this knowledge. Previous studies have focused on the impacts of collaboration on innovation and the role of academic research (Cohen et al. 2002; Klevorick et al. 1995; Nelson 1996). Studies have also focused on how collaboration with industry is affected by the motivations and constraints of researchers (Arza and Vazquez 2010; D'Este and Perkmann 2011; Perkmann et al. 2011; Tartari et al. 2012). Academia and industry operate in distinct institutional environments characterised by norms and incentives that can conflict with one another. Academic researchers generate new knowledge and publish their results in high-impact journals. Industrial scientists and engineers produce applied knowledge in the form of products and manufacturing processes (Partha and David 1994; Tartari et al. 2012).

The literature contains little evidence on how universities initiate, build and maintain collaboration with firms. Academic researchers' motivation to collaborate with industry and the role of the main outcomes of such linkages require deeper analysis (Perkmann et al. 2013; Perkmann and Walsh 2007), as does the examination of whether university–industry collaboration is a mutual strategy of firms and universities (Mascarenhas et al. 2018). In this area, previous studies have analysed the main drivers of academic researchers' collaboration with industry. Some studies have analysed how researchers' individual characteristics affect their collaboration with industry and the main drivers of such collaboration (Banal-Estañol et al. 2015; Bruneel et al. 2010; D'Este & Patel 2007). Other studies have focused on the institutional context and the role of the incentive system in place as drivers of collaboration with industry (Barletta et al. 2017; Tartari et al. 2012; Tartari and Breschi 2012). Another set of studies has focused on the relation between researchers' perceptions of collaboration and their collaboration with industry (Arza and Vazquez 2010; Bishop et al. 2011; D'Este and Perkmann 2011; Tartari and Breschi 2012). Some of these studies have focused on researchers' main motivations for engaging with industry (D'Este and Perkmann 2011), whereas

others have explored the extent to which academic researchers' decisions to collaborate with industry are explained by individual assessments of the expected benefits and costs of collaboration (Tartari and Breschi 2012).

This article makes one main contribution to the literature. While previous studies have focused on how the expected motivations of academic researchers affect their collaboration with industry (D'Este and Perkmann 2011; Tartari and Breschi 2012), we focused on how the benefits, results, and barriers the researchers perceive affect the research groups' engagement with industry. Despite the increasing number of studies analysing the main drivers of researchers' motivations to collaborate with industry, there is still a gap in the understanding of how the benefits, results, and barriers researchers perceive affect their decisions to collaborate with industry. In our analysis, we evaluate the effects on collaboration with a time lag in the explained variable to analyse how perceived benefits, results, and barriers based on researchers' previous experiences of collaboration affect research groups' engagement with industry.

To conduct this evaluation, we collected data on researchers' perceptions of benefits, results, and barriers in 2008, and we analysed how these perceptions affected the research groups' collaboration in 2010. In this way, we extend and deepen previous analysis on academic researchers' motivation to collaborate with industry, considering the benefits, results, and barriers researchers perceive based on previous experiences of collaboration and investigate how these dimensions affect decisions to collaborate. We use a database on university–industry collaboration in Brazil that covers all scientific disciplines, all industrial sectors, and all Brazilian regions. It is important to note that data on collaboration links are more widespread and more important than formal channels of technology transfer from university to industry since such data can provide a better assessment of the degree of collaboration than formal channels of interaction, such as patents, licences, or spin-offs (Banal-Estañol et al. 2015). Likely due to the lack of data, previous studies have paid little attention to these more collaborative forms of interaction between university and industry.

Although this article focuses on data from a developing country, Brazil, this case can contribute to a general understanding of how previous experiences of universities' engagement with industry can affect collaboration. As in several countries, in Brazil, universities are assuming a greater role in fostering innovation, and prominent impacts have been observed on the share of domestic firms in international markets (Chaves et al. 2016; Fernandes et al. 2010; Moraes-Silva et al. 2018; Suzigan et al. 2009; Suzigan and Albuquerque 2011). However, the less-developed institutional and economic environments suggest that university–industry collaboration could present natures and determinants different from those found in developed countries (Moraes-Silva et al. 2018). As a result, an important share of university–industry collaboration relies on the diffusion and adaptation of foreign technology. However, important and successful experiences based on long-term and systematic efforts for the development of specific capabilities have been observed in certain industries (Albuquerque et al. 2015; Moraes-Silva et al. 2018; Suzigan and Albuquerque 2011). From this perspective, university research is more important for industries with medium and medium-low levels of technology, such as coke and oil, metals, and pulp and papers, and high levels of collaboration with universities have been observed in these industries (Albuquerque 2007; Suzigan et al. 2009). As in other developing countries, in Brazil, academic research frequently acts as a substitute for firm R&D expenditures and can complement in-house industrial R&D (Rapini et al. 2009). In addition, domestic firms tend to engage in more collaborative projects than foreign firms (Chaves et al. 2012).

The remainder of this article is organised into five sections. The second section presents the main theoretical framework and addresses previous studies that have evaluated the relations between the main motivations of researchers and their engagement with industry. Section 3 presents the development of the dataset and a brief description of the application of the nonparametric item response theory (NIRT) methodology. Section 4 presents the empirical model, and Section 5 discusses the main results concerning the effects of perceived benefits, results and barriers on research groups' collaboration with industry. Finally, Section 6 presents final remarks and some policy implications.

2. Theoretical remarks

Innovation is far from an isolated process within firms. Several studies have shown the importance of external agents, such as users, suppliers, and universities that strengthen firms' in-house R&D expenditures. The increasing complexity of knowledge required for innovation has forced firms to move closer to these external sources (Mowery et al. 2004; Nelson 1996). Academic research and universities have become increasingly important sources of knowledge for both firms and society (Rosenberg and Nelson 1994). Universities have assumed an increasingly important role in fostering innovation in firms (Cohen et al. 2002; Klevorick et al. 1995) since they are key agents of the national innovation system (Mowery et al. 2004; Mowery and Sampat 2009; Nelson 1996).

However, there are several concerns regarding potential damage to the principles of open science (Merton 1973). The goals accepted as legitimate within the community of academic researchers differ from those of firms' R&D departments. The community of academic researchers is concerned with adding to the stock of public knowledge, whereas firm researchers are concerned with adding to the stream of rents that may be derived from possessing rights to the use of private knowledge. However, to ensure an efficient allocation of resources in the production of new knowledge, society must encourage both communities and maintain a synergetic equilibrium between them (Partha and David 1994).

Based on this concern, there is growing interest in evaluating the effects of university engagement with firms (Arza 2010; Bishop et al. 2011; D'Este and Patel 2007; D'Este and Perkmann 2011; Perkmann et al. 2013; Tartari et al. 2012, 2014). Studies have investigated academics' evaluations of the expected benefits and costs of their collaboration with firms (Owen-Smith and Powell 2001; Tartari and Breschi 2012). This literature is focused on understanding the relation between the motivation of academic researchers and their engagement with industry. The links with the literature lead to the following testable hypotheses. The novelty of our article is the analysis of how perceived benefits, results, and barriers affect the research groups' engagement with industry.

2.1 Benefits of collaboration

Academic researchers' collaboration with industry can yield important benefits. Many researchers engage with industry to support their research activities. Collaboration with industry is dominated by research-related motivations, including learning from industry and fundraising for research projects (D'Este and Perkmann 2011; Ramos-Vielba et al. 2016). Firms are willing to approach academic researchers because their linkages involve close collaboration.

Close collaboration facilitates interactive learning, which in turn indirectly benefits scientific production by leading to new ideas and motivating new research projects, although the distinct logics of both the university and industry are maintained in such collaboration (Perkmann et al. 2011; Perkmann and Walsh 2009). Intellectual benefits, such as improved access to industrial partnerships and the opportunity to work with industrial researchers, can allow scientists to engage in knowledge sharing, which can in turn stimulate the development of new collaborative research projects (Garrett-Jones et al. 2010).

Two main benefits that universities receive in their collaboration with firms are often noted. First, intellectual benefits can emerge from joint research projects between universities and firms with respect to industrial applications and knowledge sharing because linkages with firms can inspire new academic research projects and provide new insights for the research agenda (Arza 2010; Meyer-Krahmer and Schmoch 1998). These benefits are particularly important in the scientific fields in which academic research and industrial applications can advance simultaneously, i.e. fields in the so-called 'Pasteur Quadrant' (Stokes 1997). Intellectual benefits are one of the most important motivations for researchers to collaborate with firms, although commercial channels of interaction, such as spin-offs, licensing and patenting, can reduce these intellectual benefits (Arza and Vazquez 2010).

H1: Intellectual benefits from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

The second main benefit is economic and is related to sourcing extra funding to finance academic research (Arza 2010) or sharing equipment, materials or human resources (Davey et al. 2016; Tartari and Breschi 2012). Access to financial and nonfinancial resources is another important factor that encourages academic researchers to pursue additional collaboration with firms. Moreover, the effect of gaining access to financial and nonfinancial resources increases when the research group collaborates with industrial partners (Tartari and Breschi 2012).

H2: Economic benefits from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

2.2 Results of collaboration

With respect to the results of university–industry linkages, collaboration between university and industry can often generate important commercial results by providing opportunities to develop inventions that can be patented or licensed (Breschi et al. 2008). Similarly, collaboration can generate opportunities for academic entrepreneurship, such as spin-offs (Perkmann et al. 2013).

H3: Commercial results from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

Other important results of collaboration with industry are academic. When academic researchers work together with industry on joint projects, collaboration with firms can lead to new scientific discoveries (D'Este and Perkmann 2011). Joint research projects with industrial partners frequently result in academic publications, although publication is less likely with other types of relationships, such as research contracts and consulting, which consist of relationships with more applied purposes (Perkmann and Walsh 2009).

H4: Academic results from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

Finally, another important result of university engagement with industry is knowledge results, particularly when academic researchers collaborate with firms on projects closer to state-of-the-art knowledge. Research groups can expect to derive knowledge results from collaboration with industry, particularly for linkages related to new scientific challenges or discoveries, and such collaborations can lead to new and challenging scientific projects (Perkmann et al. 2013).

H5: Knowledge results from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

2.3 Barriers to collaboration

Furthermore, important barriers affect researchers' decisions to collaborate with industry, such as orientation (or Mertonian) barriers that are related to the main motivations and concerns of academic researchers. One of the main characteristics of the community of scientific researchers is the ability to engage in research freely and according to personal curiosity (Merton 1973). For academic researchers, engagement with industry can pose potential dilemmas related to the divergent institutional logics prevailing in academia and industry. This divergence involves the secrecy problem, which refers to the extent to which collaboration with firms imposes restrictions on the disclosure of research findings and the diffusion of research results, posing hazards to the norms of open science (Tartari et al. 2012). To secure the commercial appropriation of research results, academics may be required to delay or even forego publishing research results (Bruneel et al. 2010; Gerbin and Drnovsek 2016; Perkmann and Walsh 2009; Tartari and Breschi 2012). Thus, academic freedom may be constrained if academics are induced to move away from basic research and instead produce research based on commercial interests (Mowery et al. 2004).

The loss of academic freedom, concerns related to the secrecy of results, and restrictions on the diffusion of those results can discourage collaboration between academics and firms (Ramos-Vielba et al. 2016; Tartari et al. 2012; Tartari and Breschi 2012). However, the propensity to collaborate with industry is not significantly affected by the potential increase in secrecy or by publication delays. Thus, problems related to secrecy or the diffusion of achieved results do not appear to influence the decision to collaborate with industry (Tartari and Breschi 2012). Another important factor that can hamper university–industry linkages is the complementarity problem, which is defined as the lack of complementarity between industry-related activities and academic research. Collaboration with industry may not be considered novel or sufficiently academically innovative to warrant publication in academic journals, thus hindering the publication goals of academic researchers (Perkmann and Walsh 2009; Tartari et al. 2012). Additionally, skewing problems can arise from engagement with industry because collaboration can impose constraints on academic researchers' autonomy in establishing their own research agendas (Tartari et al. 2012).

H6: Orientation barriers from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

Another set of barriers to collaboration with industry is transactional (or Williamson) and relates to factors that can create

substantial transactional costs in such engagement. Transactional costs often require academic researchers to develop new contractual relationships with their industry partners and to navigate university technology transfer offices (TTOs) and legal departments (Davey et al. 2016; Merchán-Hernández et al. 2015; Tartari et al. 2012). University bureaucracy may also discourage collaboration with firms (Audretsch et al. 2002; Salimi et al. 2016). Although senior management at the university may be committed to engagement with industry, operational levels may exacerbate the risk of interaction with firms and create barriers to collaborative contracts.

H7: Transactional barriers from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

Certain barriers are related to capability barriers because the lack of skills among university staff, particularly in TTOs, may hamper the engagement of academic researchers in university–industry joint projects (Owen-Smith and Powell 2001; Tartari et al. 2012). On the university side, underfunded or understaffed TTOs can produce long delays, awkward schedules, lax reporting, and slow responsiveness to the concerns of academic researchers in the collaboration process. On the industry side, the lack of skilled R&D and engineering staff may hinder linkages with academic researchers. Regarding barriers, other testable hypotheses can be presented.

H8: Capability barriers from academic researchers' previous experience of collaboration positively affect research groups' collaboration with industry

3. The development of the database

3.1. Data

The main data used in this article came from a survey of Brazilian research groups that collaborate with firms. We collected data in the spring of 2008 from a questionnaire distributed to the leaders of research groups across the country in every scientific discipline. We selected research groups that had reported collaboration with firms to the Brazilian Council for Scientific and Technological Development (CNPq), and we sent the questionnaires as electronic surveys to 2,151 research group leaders who had collaborated with industry in 2004. We received 1,005 valid responses. The researchers separately evaluated the benefits, results, and barriers according to importance using a 4-point scale Likert ('not important', 'slightly important', 'moderately important', and 'very important'). In their answers to the questionnaire, the researchers revealed their perception of the importance of the benefits, results, and barriers of their collaboration with industry. In addition to covering collaboration, the information collected by the questionnaire covered the main characteristics of the research group, such as its size, scientific field, and location. The questionnaire also included other aspects of the collaboration, such as the channels of interaction and the type of funding for the collaborative projects.

To this dataset, we added time-lagged data on the number of collaborative engagements of each of these 1,005 research groups in 2010 (data from the Brazilian Council for Scientific and Technological Development—CNPq). We merged this dataset with the 2010 data, which allowed us to obtain 765 research groups in Brazil, belonging to 137 universities throughout the country and covering all scientific disciplines. They participated in 1,624 collaborative projects with firms from several industrial sectors. Our final sample presents a distribution that is very similar to that of the original sample regarding scientific disciplines and location. We use data on university–industry collaborative projects instead of formal channels of interactions, such as patents, licences and spin-offs. Data on collaboration with industry present several advantages because collaborative projects with industry are widespread and important for technology transfer from university to industry (Agrawal and Henderson 2002; Banal-Estañol et al. 2015; Cohen et al. 2002; D'Este and Patel 2007).

3.2. Nonparametric item response theory

We used the nonparametric item response theory (NIRT) technique to identify clusters from the pattern of responses and define dimensions for benefits, results, and barriers. This technique allowed us to reduce the number of items for each dimension and assess how these items are related. The NIRT technique also allows the estimated model to more adequately consider the clusters of items and provides an appropriate estimation for improved interpretation of the coefficients. This technique allows scales (cluster of items) to be identified from the pattern of responses that an individual produces through questionnaires by generating *ex post* clusters, which avoids arbitrariness in the selection of groups of variables. At least three additional advantages are observed in the use of NIRT. First, NIRT selects items sequentially one by one. Secondly, different choices for association measures are used to analyse the associations between the items. Thirdly, NIRT yields a measurement model based on the assumptions of unidimensionality, local independence, and monotonicity (Paas and Sijtsma 2007). In addition, the NIRT technique was specifically created to generate scales from information collected by questionnaires and sometimes comprising several dimensions, as in the survey questionnaire used in this article.

The application of NIRT for each dimension allows groups of items that form a coherent scale to be identified because the clustered items show adequate levels of scalability (H-index) at a significance level of 5%. The results for each dimension are presented in Table 1, which shows the clustered items and their H-index scores. The table also shows the number of respondents and the share of 'moderately important' and 'very important' answers for each category. We performed the NIRT analysis with the 'mokken' package of the R statistical software. An H-index value ≥ 0.5 is considered strong, and the lower limit was 0.3 (Mokken 1971).

The application of NIRT techniques to the benefits dimension allows two clusters to be identified (Table 1). The first group covers the *intellectual benefits*, which include intellectual and tacit benefits, such as reputation and networks. The second group comprises *economic benefits* and aggregates items related to the material or financial benefits obtained by interacting with firms. The importance of intellectual benefits, measured by the share of 'moderately important' and 'very important' answers, is higher than that of economic benefits, which may indicate that researchers tend to regard the intellectual benefits arising from the collaboration as more important. We use these clusters to test H1 and H2.

The clustered items for the dimension results show that two clusters are related to academic purposes, *knowledge results* and *academic results*. The third cluster is *commercial results*, which consists of items linked to the industrial applications of academic research results. The researchers considered the results linked to knowledge and academic activities to be more important than industrial application, which may indicate the research groups' increasing attraction to the intellectual results of their collaboration with firms. We use these clusters to test H3, H4, and H5.

Table 1. NIRT clusters of benefits, results and barriers.

Dimension	Cluster	Item	Moderately and Very important	%	H-index
Benefits	Intellectual benefits	Ideas for new collaborative projects	630	82.4	0.66
		New ideas for research projects	663	86.7	0.69
		Interchange of information or knowledge	625	81.7	0.63
		New network relationships	554	72.4	0.65
		Reputation	543	71	0.64
	Economic benefits	Joint use of equipment labs	412	53.9	0.55
		Receipt of inputs for research	531	69.4	0.65
		Financial resources	534	69.8	0.6
	Knowledge results	New scientific discoveries	478	62.5	0.6
Results		New research projects	658	86	0.6
	Academic results	Training	633	82.7	0.59
		Theses and dissertations	627	82	0.69
		Publications	619	80.9	0.63
	Commercial results	New products and devices	447	58.4	0.59
		New manufacturing processes	352	46	0.64
		Improved products	354	46.3	0.63
		Improved manufacturing processes	373	48.8	0.62
		Patents	350	45.8	0.56
		Design	147	19.2	0.56
		Academic entrepreneurship and spin-offs	183	23.9	0.58
Barriers	Capability barriers	Lack of knowledge about universities' activities	453	59.2	0.61
		Lack of knowledge of the needs of firms	464	60.7	0.6
		Lack of professionals to dialogue with academic researchers	363	47.5	0.61
		Lack of professionals to dialogue with firms	394	51.5	0.62
	Orientation barriers	Differences on priorities	443	57.9	0.51
		Differences on research deadlines	298	39	0.51
	Transactional barriers	Bureaucracy in the firm	360	47.1	0.31
		Bureaucracy in the university	587	76.7	0.36
		Costs	485	63.4	0.36
		Trust	231	30.2	0.38
		Intellectual Property	333	43.5	0.38

Source: Own elaboration; there are also two unscalable items: software and geographical distance.

Finally, three clustered items were identified in the dimension barriers to test H6, H7, and H8. *Capability barriers* involve the difficulties experienced by research groups and firms due to the lack of knowledge and communication skills in both the firms and academia. *Orientation barriers* encompass differences in priorities and deadlines between firms and academia that are consistent with their different orientations (Merton 1973). The third cluster consists of *transactional barriers*, which comprise a set of factors regarding the formalisation and legitimation of the engagement between firms and academia, i.e. the so-called 'Williamson barriers' (Tartari et al. 2012).

Analysing the evaluation of the importance of each dimension for collaboration ensures that a share of the responses will be 'moderately important' and 'very important' for each cluster of items (Table 1). Intellectual benefits are the most important benefit highlighted by the researchers. Among the results, academic and knowledge results present higher medians. Finally, the barriers show similar importance because the median for each cluster is ~50%. The definition of the main clusters for each dimension can be linked to the literature regarding the benefits, results, and barriers associated with university engagement with industry (Table 2). Each identified cluster has strong relationships with previous findings in the literature.

4. Econometric approach

The aim of this article is to analyse how the benefits, results, and barriers researchers perceive in collaboration affect academic research groups' engagement with industry. Empirically, we model the relation of the clusters generated by the NIRT technique in each dimension of the academic researchers' perceptions of benefits, results, and barriers with the number of collaborative projects each of the 765 research groups carried out in 2010. The dependent variable (*Collab*) is the number of collaborative projects for each research group. To avoid endogeneity due to simultaneity between the number of collaborative projects and the identified clusters of each dimension, we gathered data on the collaboration of the research groups in 2010. In this way, we were able to relate the identified clusters of the researchers' perceptions of the dimensions of benefits, results, and barriers in 2008 with the number of collaborative projects for each research group in 2010. Because of this temporal lag, we can examine how the benefits, results, and barriers the researchers perceive affected their collaboration with industry.

The main explanatory variables are the identified clusters of each dimension. The use of the NIRT technique to generate the clusters of items allowed us to avoid multicollinearity. In addition, we included controls, such as the size of the research group (*Size*), because larger research groups have greater human, physical, and

Table 2. Theoretical background and the NIRT clusters.

Intellectual benefits	Intellectual benefits (Arza and Vazquez 2010)
	Resources (Tartari and Breschi 2012)
	Learning (D'Este and Perkmann 2011)
	References for public project and knowledge exchange (Meyer-Krahmer and Schmoch 1998)
Economic benefits	Access to in-kind resources and funding (D'Este and Perkmann 2011)
	Resources (Tartari and Breschi 2012)
	Additional facilities and additional funds, flexibility of industrial funds (Meyer-Krahmer and Schmoch 1998)
	Economics benefits (Arza and Vazquez 2010)
Knowledge results	New research projects (Perkmann et al. 2013)
Academic results	Publications (Perkmann and Walsh 2009)
Commercial results	Commercialisation (D'Este and Perkmann 2011; Perkmann et al. 2013)
Capability barriers	Skills of university (or TTOs) staff (Owen-Smith and Powell 2001)
	Managerial problems (Meyer-Krahmer & Schmoch 1998)
Orientation barriers	Freedom and secrecy (Tartari et al. 2012; Tartari & Breschi 2012)
	Complementarity (Perkmann & Walsh 2009)
	Subject skewing (Tartari et al. 2012)
	Restrictions to publications and short-term orientation (Meyer-Krahmer & Schmoch 1998)
Transactional barriers	Technology transfer problems (Owen-Smith and Powell 2001)
	Williamson barriers (Tartari et al. 2012)
	Bureaucracy (Audretsch et al. 2002)

Source: Own elaboration.

financial resources for academic research and a greater ability to collaborate with industry (De Fuentes and Dutrénit 2012; Mansfield and Lee 1996; Perkmann et al. 2011; Schartinger et al. 2001); the share of funding of the research group from private firms (*Finan*); and a dummy variable for research groups linked to public research institutes (*PRI*) because these institutes play a substantial role in developing countries (Mazzoleni and Nelson 2007). We also added two regional variables: a dummy variable for the South and Southeast regions (*SSE*) because of the unequal regional distribution of R&D expenditures among Brazilian regions (Garcia et al. 2015) and the share of the manufacturing industry in the total employment of the firm's region (*Manuf*). Finally, we added dummy variables that control for scientific fields (*Areas*) (Bekkers and Bodas Freitas 2008; Meyer-Krahmer and Schmoch 1998) and for collaboration channels (*Channel*) (Arza 2010; De Fuentes and Dutrénit 2012). We estimated the following regression model for the whole sample of research groups.

$$\begin{aligned} Collab_t = {} & \beta_1 Intel\_Benefits_{t-1} + \beta_2 Econ\_Benefits_{t-1} \\ & + \beta_3 Com\_Results_{t-1} + \beta_4 Acad\_Results_{t-1} \\ & + \beta_5 Know\_Results_{t-1} + \beta_6 Orie\_Barriers_{t-1} \\ & + \beta_7 Trans\_Barriers_{t-1} + \beta_8 Capac\_Barriers_{t-1} \\ & + Controls_{t-1} \end{aligned}$$

The main variables and their proxies are presented in Table 3, and the descriptive statistics are presented in Table 4.

5. Results and discussion

We conducted five main estimations using negative binomial regression to analyse how the benefits, results, and barriers perceived in previous experiences of collaboration affect academic researchers' engagement with industry. Model (1) is the baseline model and contains only controls. Models (2), (3), and (4) add each dimension separately. Finally, we tested the full model (5). The signs of the coefficients are consistent with the previous specification, and a slight increase in R^2 is observed. The comparison of these models with the full model reinforces the quality of the estimations since both the analysed dimensions and the controls present almost no change in the significance of the coefficients. The results are presented in Table 5.

The main findings show that *intellectual benefits* and *commercial results* have positive and significant coefficients, whereas *economic benefits* and *transactional barriers* have negative and significant coefficients.

Regarding benefits, *intellectual benefits* positively affect research groups' collaboration with firms, which supports H1. Our findings show that researchers who recognise the intellectual benefits related to their previous collaborations with industry collaborate more than those who do not. Thus, when researchers recognise that collaboration with industry can lead to ideas for new collaborative projects, new ideas for research projects, knowledge sharing, new network relationships, and reputation, they tend to collaborate more with industry. This result can be reinforced when combined with previous findings in the literature regarding the importance of the intellectual benefits to collaborative researchers (Arza and Vazquez 2010; D'Este and Perkmann 2011; Garrett-Jones et al. 2010; Perkmann and Walsh 2009). Engagement with industry has a substantial effect on the development of new research projects at the university because intellectual benefits represent an important driving factor for collaboration (Arza and Vazquez 2010; D'Este and Perkmann 2011). In addition to these previous findings, we found that researchers who already collaborate with industry recognise the importance of the intellectual benefits linked to their collaboration. Thus, collaboration with industry is frequently beneficial for research groups because academic researchers can generate new insights and ideas for the development of new academic research projects through these linkages, thereby bringing new research questions to the university. Furthermore, engagement with industry can bring new ideas for new cooperative projects with industry. This finding also reveals the importance of collaboration over time since the increasing experience of the partners can reinforce the intellectual benefits for academic research, especially considering that this experience can be achieved over time.

Table 3. Variables description.

Variable	Description	Source
Collab	Count of the collaboration of the research group with firms	CNPq, 2010
Benefits	Sum of the score for items pertaining to each cluster (Intellectual and Economic)	Own elaboration based on NIRT; data from Survey, 2008
Results	Sum of the score for items pertaining to each cluster (Knowledge, Academic and Commercial)	
Barriers	Sum of the score for items pertaining to each cluster (Capability, Orientation and Transactional)	
Size	Total number of members in the research group	Survey, 2008
Finan	Share of research funds received by firms (%)	Survey, 2008
Manuf	Regional share of employment in manufacturing industry	RAIS, 2008
PRI	Dummy for Public Research Institutes	Survey, 2008
SSE	Dummy for South-Southeast regional	Survey, 2008
Area	Dummies for scientific field	Survey, 2008
Channel	Sum of the score for items pertaining to each channel of collaboration	Survey, 2008

Source: Own elaboration.

Table 4. Descriptive statistics.

Variable		Mean	Std. Dev.	Min	25%	50%	75%	Max
Collab		2.12	3.01	0	0	1	3	30
Benefits	Intellectual			5	14	17	19	20
	Economic			3	6	9	11	12
Results	Knowledge			2	5	6	8	8
	Academic			3	9	11	12	12
	Commercial			7	9	14	21	28
Barriers	Capability			4	7	10	13	16
	Orientation			2	3	5	6	8
	Transactional			5	10	13	15	20
Size		22.59	16.82	0	12	18	28	138
Finan		0.32	0.33	0	0	0.2	0.6	1
Manuf		0.19	0.06	0.02	0.15	0.21	0.23	0.32

Source: Own elaboration.

With respect to *economic benefits*, the coefficients are negative and significant, which leads to the rejection of H2. This result shows that research groups that assigned higher importance to the economic benefits related to their collaboration, such as the joint use of lab equipment, research inputs, and financial resources, are involved in fewer collaborative projects with industry than those that do not. Previous studies that have analysed the effects of economic benefits expected from collaboration have shown that obtaining resources is a relevant motivation for collaborating with firms (Tartari and Breschi 2012). However, our results go in the other direction, as among academic researchers who already collaborate with industry, perceived economic benefits from collaboration do not represent a motivation to increase the number of collaborative projects over time. This result could mean that academic researchers who realise greater economic benefits from collaboration can be encouraged to focus on specific projects with specific industrial partners, resulting in a decrease in the number of collaborative projects over time. Our results yield this finding because we use a time lag to analyse the number of collaborative projects of the research groups, which is in contrast to previous studies that evaluate the effects of expected economic benefits (Tartari and Breschi 2012). Is this way, expected economic benefits could be a motivation for collaboration, but perceived economic benefits encourage researchers to decrease the number of collaborative projects and focus on specific industrial partners. In addition, this finding may indicate that academic researchers give more importance to the intellectual benefits associated with collaboration with firms than to tangible benefits, which might further indicate that intellectual benefits frequently outweigh the financial assistance related to engagement with industry (Fernandes et al. 2010).

Commercial results also positively affect researchers' decision to increase their collaboration with industry, which supports H3. This finding shows that researchers who recognise the importance of commercial results, such as new or improved products and processes, patents, and spin-offs, tend to collaborate more with industrial partners. This result further indicates the occurrence of self-reinforcement mechanisms and positive feedback between collaboration and commercial results over time. Engagement with industry can provide opportunities for academic researchers to develop new inventions that can be patented and licensed, and collaboration can create opportunities for academic entrepreneurship and spin-offs (Perkmann et al. 2013). This result can also be understood in the context of developing countries, where universities and public research institutes play an important and increasing role in supporting innovation, sometimes substituting private efforts for innovation (Albuquerque et al. 2015; Suzigan et al. 2009). In this way, our findings from the Brazilian context show the importance of the generation of new and improved products and processes that arise from the collaborative projects between the university and industry.

Knowledge results and *academic results* do not present significant coefficients (H5 and H4). This result indicates that academic researchers who collaborate more with firms do not tend to consider

Table 5. Coefficients estimation—negative binomial regression for collaboration counts.

		(1)	(2)	(3)	(4)	(5)
Benefits	Intellectual		0.038**			0.044**
			(0.14)			(0.15)
	Economic		−0.067**			−0.063**
			(0.02)			(0.23)
Results	Knowledge			−0.037		−0.033
				(0.31)		(0.33)
	Academic			−0.007		−0.019
				(0.21)		(0.22)
	Commercial			0.012		0.017†
				(0.01)		(0.01)
Barriers	Capability				0.021	0.018
					(0.01)	(0.14)
	Orientation				0.003	−0.001
					(0.03)	(0.31)
	Transactional				−0.041*	−0.038*
					(0.02)	(0.02)
Size		0.011***	0.011***	0.011***	0.011***	0.011***
		(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
Finan		0.321**	0.394**	0.334**	0.329**	0.397***
		(0.13)	(0.14)	(0.13)	(0.13)	(0.14)
Manuf		−0.466	−0.377	−0.475	−0.347	−0.287
		(0.79)	(0.79)	(0.79)	(0.80)	(0.78)
Controls	Dummy PRI	Yes	Yes	Yes	Yes	Yes
	Dummy SSE	Yes	Yes	Yes	Yes	Yes
	Dummies for Areas	Yes	Yes	Yes	Yes	Yes
	Channels	Yes	Yes	Yes	Yes	Yes
Constant		−0.281	−0.386	−0.219	−0.223	−0.276
		(0.26)	(0.27)	(0.27)	(0.27)	(0.28)
Number of observations		765	765	765	765	765
LR chi^2		96.50	107.31	99.13	103.10	117.10
Prob>chi^2		0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood		−1449.28	−1443.87	−1447.97	−1445.98	−1438.99
Pseudo R2		0.0322	0.0358	0.0331	0.0344	0.0391

***$P < 0.1\%$;
**$P < 1\%$;
*$P < 5\%$;
†$P < 10\%$; Standard error in parentheses.
Source: Own elaboration.

knowledge results, such as new scientific discoveries and new research projects, or academic results, such as researcher training, publications, and theses and dissertations, as drivers of the decision to collaborate more with firms. This result can also be understood in the context of developing countries since a large proportion of the collaborative projects between universities and firms do not involve state-of-the-art scientific and technological development and therefore produce less knowledge and academic results. Nevertheless, collaborative projects with academic researchers are important tools for the diffusion of new knowledge among local producers, which can improve their competitiveness. Finally, it is important to note that researchers' responses concerning the importance of each dimension demonstrate that academic and knowledge results carry similarly high importance (Table 1). This assures the role of academic and knowledge results for the researchers who collaborate with industry, even if such results do not correlate with the number of collaborative projects.

Regarding barriers, the results show that *transactional barriers* have a negative effect on the number of collaborative projects research groups become involved in, thereby supporting H7. This result suggests that researchers who report transactional barriers as more relevant collaborate less with industrial partners than those who do not. These transactional barriers include bureaucracy (at both universities and firms), contract costs, lack of trust, and intellectual property. *Orientation barriers* do not present significant coefficients (H6), which may indicate that among Brazilian research groups that collaborate with industry, orientation (or Mertonian) problems are not related to the number of collaborative projects the research groups engage in. Thus, researchers engaging with firms can establish collaborative projects with industrial partners without hindering the university's mission of generating new knowledge and publishing in high-impact journals. The potential increase in secrecy and publication delays does not affect academic researchers' propensity to collaborate with industry (Tartari and Breschi 2012). *Capability barriers* also present no significant coefficients (H8), which suggest that problems related to capabilities, even knowledge or communication, in universities or in firms do not affect the number of collaborative projects the research groups become involved in. It is notable that researchers generally attribute the same importance to the three dimensions of barriers: capabilities, orientation, and transactional barriers (Table 1). However, only transactional barriers negatively affect the number of collaborative projects of the research groups.

Regarding controls, the size of the research group (*Size*) has a positive effect on the number of collaborative projects a research group might have. This result indicates that compared to smaller research groups, larger research groups can better handle broader and, in several cases, more diversified academic skills, which improves their ability to collaborate with firms. The share of private funding (*Finan*) also presents positive and significant coefficients, which shows the role of private funding in stimulating research groups to collaborate more. Finally, the dummies for channels of collaboration and scientific fields also present significant coefficients and show different patterns of collaboration with industry among different channels of collaboration and scientific fields of research groups.

6. Final remarks and policy implications

In this article, we analyse how the benefits, results, and barriers researchers perceive from collaboration affect academic research groups' engagement with industry. We assume that academia has become a growing source of information and knowledge for firm innovation, which increases the importance of university–industry collaboration. Thus, it is important to understand what drives academic researchers to engage with industrial partners (Perkmann et al. 2013). We apply this subject to a comprehensive database on university–industry collaboration in Brazil, and we use a time lag to analyse the number of collaborative projects the research groups become involved in, which allows us to analyse how the researchers' perceptions regarding benefits, results, and barriers for collaboration affect their collaboration with industry. Previous studies have also analysed the main drivers of researchers' motivation to collaborate with industry, but they have done so using expected outcomes and costs related to collaboration (D'Este and Perkmann 2011; Tartari and Breschi 2012). In this way, the novelty of this article is that we use the researchers' evaluation of the benefits, results, and barriers associated with their previous collaboration and we analyse how these aspects affect the research groups' collaboration with industry.

We make four major main points. First, the perceived intellectual benefits of collaboration with industrial partners, such as new ideas for cooperative projects, new ideas for research projects, information and knowledge sharing, new network relationships, and reputation, positively affect research groups' collaboration. Secondly, perceived economic benefits, such as the joint use of lab equipment, research inputs, and financial resources, despite their importance for researchers who collaborate with industry, discourage academic research groups from increasing the number of collaborative projects. Thirdly, the commercial results of previous cooperation with firms, such as new or improved products and processes, patents and spin-offs, also increase the number of collaborative projects a researcher engages in with firms. Finally, perceived transactional barriers, such as bureaucracies in both universities and firms, contract costs, trust, and intellectual property, play an important role in discouraging research groups from collaborating more with industrial partners.

Our findings represent new empirical evidence contributing to the understanding of academic researchers' engagement in collaborative projects with industry. In fact, understanding the individual perceptions that lead academic researchers to engage with industry contributes to the broader issue of how universities should manage and encourage academics to act proactively and collaborate with industrial partners. Our results suggest that direct incentives regarding intellectual benefits are important tools that encourage academic researchers to decide to collaborate more with industry. Engagement with industry can produce intellectual benefits for researchers who collaborate with industrial partners, and ideas for new scientific projects and exchange of information and knowledge are important benefits related to collaboration with firms. This result is strengthened by other findings that show that orientation barriers are not significant, which means that the researchers encountered no orientation problems as a barrier to additional collaboration with firms. Commercial results are also important drivers of research groups' engagement with firms, which means that researchers who collaborate more with industrial partners can generate commercial results, such as new and improved products and processes and patents. This result indicates the important role of the university in supporting innovation, especially through collaborative projects with firms. Thus, these findings yield a greater understanding of the main motivations and constraints of researchers who collaborate with industrial partners and strengthen the sharing of academic knowledge with firms.

Finally, these findings have policy implications. In general, our findings reveal the main important conditions under which academic researchers are willing to collaborate more with industry. To encourage collaboration between university and industry, policy makers should emphasise and facilitate access to resources for academic research and ensure the generation of academic results through collaboration. Concerning the importance of intellectual benefits and academic results, policy measures geared towards stimulating university–industry collaboration do not hinder academic activity but strengthen the capacity of researchers to generate academic results, such as publications, theses, and dissertations. Thus, policy measures should encourage collaborative projects between universities and firms and the implementation of state-of-the-art academic knowledge through industrial applications because such efforts are useful not only for firm innovation but also for the generation of new ideas for academic research projects, including collaborative projects. Policies should include requirements regarding the generation of academic outcomes, such as publications.

Regarding transactional barriers, which negatively affect the engagement of researchers with industry, policy should simplify procedures related to contracts with firms and make them more transparent. This task is significant not only for policy makers but also for university TTOs because simpler contracts may represent an important method of stimulating cooperation with industrial partners. It is also necessary to design clear regulations for university–industry relationships to maintain an efficient equilibrium between basic research, concerned with the long term, and more applied industrial research, oriented towards the short term (Partha and David 1994; Tartari and Breschi 2012). Because of the role of intellectual benefits in motivating academic researchers to collaborate, university managers and policy makers should also create a set of norms and regulations that guarantee academic autonomy and research freedom, even when researchers are using private funding sources. These regulations are even more important in developing countries, where university research supports the lack of industrial R&D expenditures in several areas. Further implications from the recognition of the role of intellectual benefits include the need to adjust institutional frameworks in the universities of developing countries to encourage university researchers to work more closely with industrial partners (Barletta et al. 2017)(Barletta et al. 2017). These changes could be made by adapting regulations, incentives, and the evaluation systems of academic researchers engaged with industrial partners.

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References

Agrawal, A., and Henderson, R. (2002) 'Putting Patents in Context: Exploring Knowledge Transfer from MIT', *Management Science*, 48/1: 44–60.

Albuquerque, E. M. (2007) 'Inadequacy of Technology and Innovation Systems at the Periphery', *Cambridge Journal of Economics*, 31/5: 669–90.

———, Suzigan, W., Kruss, G., and Lee, K. (2015). *Developing National Systems of Innovation: University-Industry Interactions in the Global South*. Cheltenham, UK: Edward Elgar Publishing.

Arza, V. (2010) 'Channels, Benefits and Risks of Public–Private Interactions for Knowledge Transfer: Conceptual Framework Inspired by Latin America', *Science and Public Policy*, 37/7: 473–84.

———, and Vazquez, C. (2010) 'Interactions between Public Research Organisations and Industry in Argentina', *Science and Public Policy*, 37/7: 499–511.

Audretsch, D. B., Bozeman, B., Combs, K. L., Feldman, M. et al. (2002) 'The Economics of Science and Technology', *The Journal of Technology Transfer*, 27/2: 155–203.

Banal-Estañol, A., Jofre-Bonet, M., and Lawson, C. (2015) 'The Double-edged Sword of Industry Collaboration: Evidence from Engineering Academics in the UK', *Research Policy*, 44/6: 1160–75.

Barletta, F., Yoguel, G., Pereira, M., and Rodríguez, S. (2017) 'Exploring Scientific Productivity and Transfer Activities: Evidence from Argentinean ICT Research Groups', *Research Policy*, 46/8: 1361–9.

Bekkers, R., and Bodas Freitas, I. M. (2008) 'Analysing Knowledge Transfer Channels between Universities and Industry: To What Degree do Sectors also Matter?', *Research Policy*, 37/10: 1837–53.

Bishop, K., D'Este, P., and Neely, A. (2011) 'Gaining from Interactions with Universities: Multiple Methods for Nurturing Absorptive Capacity', *Research Policy*, 40/1: 30–40.

Breschi, S., Lissoni, F., and Montobbio, F. (2008) 'University Patenting and Scientific Productivity: A Quantitative Study of Italian Academic Inventors', *European Management Review*, 5/2: 91–109.

Bruneel, J., D'Este, P., and Salter, A. (2010) 'Investigating the Factors that Diminish the Barriers to University-Industry Collaboration', *Research Policy*, 39/7: 858–68.

Chaves, C. V., Carvalho, S. S. M., Silva, L. A., Teixeira, T. C. et al. (2012) 'The Point of View of Firms in Minas Gerais about the Contribution of Universities and Research Institutes to R & D Activities', *Research Policy*, 41/9: 1683–95.

———, Rapini, M. S., Suzigan, W., Fernandes, A. C. A. et al. (2016) 'The Contribution of Universities and Research Institutes to Brazilian Innovation System', *Innovation and Development*, 6/1: 31–50.

Cohen, W. M., Nelson, R. R., and Walsh, J. P. (2002) 'Links and Impacts: The Influence of Public Research on Industrial R&D', *Management Science*, 48/1: 1–23.

D'Este, P., and Patel, P. (2007) 'University-Industry Linkages in the UK: What are the Factors Underlying the Variety of Interactions with Industry?', *Research Policy*, 36/9: 1295–313.

———, and Perkmann, M. (2011) 'Why do Academics Engage with Industry? The Entrepreneurial University and Individual Motivations', *Journal of Technology Transfer*, 36/3: 316–39.

Davey, T., Rossano, S., and van der Sijde, P. (2016) 'Does Context Matter in Academic Entrepreneurship? The Role of Barriers and Drivers in the Regional and National Context', *Journal of Technology Transfer*, 41/6: 1457–82.

Fernandes, A. C., de Souza, B. C., da Silva, A. S., Suzigan, W. et al. (2010) 'Academy-Industry Links in Brazil: Evidence about Channels and Benefits for Firms and Researchers', *Science and Public Policy*, 37/7: 485–98.

De Fuentes, C., and Dutrénit, G. (2012) 'Best Channels of Academia-Industry Interaction for Long-term Benefit', *Research Policy*, 41/9: 1666–82.

Garcia, R., Araujo, V., Mascarini, S., Santos, E. G. et al. (2015) 'Looking at both Sides: how Specific Characteristics of Academic Research Groups and Firms Affect the Geographical Distance of University–Industry Linkages', *Regional Studies, Regional Science*, 2/1: 518–34.

Garrett-Jones, S., Turpin, T., and Diment, K. (2010) 'Managing Competition Between Individual and Organizational Goals in Cross-Sector Research and Development Centres', *Journal of Technology Transfer*, 35/5: 527–46.

Gerbin, A., and Drnovsek, M. (2016) 'Determinants and Public Policy Implications of Academic-Industry Knowledge Transfer in Life Sciences: A Review and a Conceptual Framework', *Journal of Technology Transfer*, 41/5: 979–1076.

Klevorick, A. K., Levin, R. C., Nelson, R. R., and Winter, S. G. (1995) 'On the Sources and Significance of Interindustry Differences in Technological Opportunities', *Research Policy*, 24/2: 185–205.

Mansfield, E., and Lee, J. Y. (1996) 'The Modern University: Contributor to Industrial Innovation and Recipient of Industrial R & D support', *Research Policy*, 25/7: 1047–58.

Mascarenhas, C., Ferreira, J. J., and Marques, C. (2018) 'University–Industry Cooperation: A Systematic Literature Review and Research Agenda', *Science and Public Policy*, 2018: 1–11.

Mazzoleni, R., and Nelson, R. R. (2007) 'Public Research Institutions and Economic Catch-up', *Research Policy*, 36/10: 1512–28.

Merchán-Hernández, C., Valmaseda-Andia, O., and Fernández-Esquinas, M. (2015) 'The Challenges of Connecting Science–Industry in Peripheral Regions: Researchers' Attitudes and Organizational and Institutional Features as Determinants', *European Planning Studies*, 23/12: 2600–20.

Merton, R. K. (1973). *The Sociology of Science: Theoretical and Empirical Investigations*. Chicago and London: The University of Chicago Press.

Meyer-Krahmer, F., and Schmoch, U. (1998) 'Science-based Technologies: University – Industry Interactions in Four Fields', *Research Policy*, 27/8: 835–51.

Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis. With Applications in Political Research*, Berlin: De Gruyter Mouton.

Moraes-Silva, D. R., Furtado, A. T., and Vonortas, N. S. (2018) 'University-Industry R&D Cooperation in Brazil: A Sectoral Approach', *The Journal of Technology Transfer*, 43/2: 285–315.

Mowery, D. C., Nelson, R. R., Sampat, B. N., Ziedonis, A. A. et al. (2004). *Ivory Tower and Industrial Innovation University-Industry Technology Transfer Before and After the Bayh-Dole Act*. Stanford: Stanford University Press.

———, and Sampat, B. N. (2009) 'Universities in National Innovation Systems'. In: J. Fagerberg and D. D. Mowery (eds) *The Oxford Handbook of Innovation*, pp. 209–39. Oxford Handbooks Online.

Nelson, R. R. (1996). *The Sources of Economic Growth*. Cambridge, MA: Harvard University Press.

Owen-Smith, J., and Powell, W. W. (2001) 'To Patent or not: Faculty Decisions and Institutional Success at Technology Transfer', *The Journal of Technology Transfer*, 26/1: 99–114.

Paas, L. J., and Sijtsma, K. (2007) 'Nonparametric Item Response Theory for Investigating Dimensionality of Marketing Scales: A SERVQUAL Application', *Marketing Letters*, 19/2: 157–70.

Partha, D., and David, P. A. (1994) 'Toward a New Economics of Science', *Research Policy*, 23/5: 487–521.

Perkmann, M., King, Z., and Pavelin, S. (2011) 'Engaging Excellence? Effects of Faculty Quality on University Engagement with Industry', *Research Policy*, 40/4: 539–52.

——, Tartari, V., McKelvey, M., Autio, E. et al. (2013) 'Academic Engagement and Commercialisation: A Review of the Literature on University-Industry Relations', *Research Policy*, 42/2: 423–42.

——, and Walsh, K. (2007) 'University-Industry Relationships and Open Innovation: Towards a Research Agenda', *International Journal of Management Reviews*, 9/4: 259–80.

——, and —— (2009) 'The Two Faces of Collaboration: Impacts of University-Industry Relations on Public Research', *Industrial and Corporate Change*, 18/6: 1033–65.

Ramos-Vielba, I., Sanchez-Barrioluengo, M., and Woolley, R. (2016) 'Scientific Research Groups' Cooperation with Firms and Government Agencies: Motivations and Barriers', *Journal of Technology Transfer*, 41/3: 558–85.

Rapini, M. S., Albuquerque, E. M., Chave, C. V., Silva, L. A. et al. (2009) 'University-Industry Interactions in an Immature System of Innovation: Evidence from Minas Gerais, Brazil', *Science and Public Policy*, 36/5: 373–86.

Rosenberg, N., and Nelson, R. R. (1994) 'American Universities and Technical Advance in Industry', *Research Policy*, 23/3: 323–48.

Salimi, N., Bekkers, R., and Frenken, K. (2016) 'Success Factors in University–Industry PhD Projects', *Science and Public Policy*, 43/6: 812–30.

Schartinger, D., Schibany, A., and Gassler, H. (2001) 'Interactive Relations Between Universities and Firms: Empirical Evidence for Austria', *The Journal of Technology Transfer*, 26/3: 255–68.

Stokes, D. E. (1997) *Pasteur's quadrant: basic science and technological innovation*. Washington: Brookings Institution Press.

Suzigan, W., Albuquerque, E., Garcia, R., and Rapini, M. (2009) 'University and Industry Linkages in Brazil: Some Preliminary and Descriptive Results', *Seoul Journal of Economics, 22*/4: 591–611.

——, and Albuquerque, E. M. (2011) 'The Underestimated Role of Universities for the Brazilian System of Innovation', *Revista de Economia Política*, 31/1: 03–30.

Tartari, V., and Breschi, S. (2012) 'Set them Free: Scientists' Evaluations of the Benefits and Costs of University-Industry Research Collaboration', *Industrial and Corporate Change*, 21/5: 1117–47.

——, Perkmann, M., and Salter, A. (2014) 'In Good Company: The Influence of Peers on Industry Engagement by Academic Scientists', *Research Policy*, 43/7: 1189–203.

——, Salter, A., and D'Este, P. (2012) 'Crossing the Rubicon: Exploring the Factors that Shape Academics' Perceptions of the Barriers to Working with Industry', *Cambridge Journal of Economics*, 36/3: 655–77.